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Managing Emergent Surgery for Ruptured Abdominal Aortic Aneurysm during the COVID-19 Pandemic

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Background: Coronavirus disease 2019 (COVID-19) has become a global pandemic which may compromise the management of vascular emergencies. An uncompromised treatment for ruptured abdominal aortic aneurysm (rAAA) during such a health crisis represents a challenge. This study aimed to demonstrate the treatment outcomes of rAAA and the perioperative prevention of cross-infection under the COVID-19 pandemic.

Conflict of interest: None to be declared by the authors.

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Methods: In cases of rAAA during the pandemic, a perioperative workflow was applied to expedite coronavirus testing and avoid pre-operative delay, combined with a strategy for preventing cross-infection. Data of rAAA treated in 11 vascular centers between January-March 2020 collected retrospectively were compared to the corresponding period in 2018 and 2019.

Results: Eight, 12, and 14 rAAA patients were treated in 11 centers in January-March 2018, 2019, and 2020, respectively. An increased portion were treated at local hospitals with a comparable outcome compared with large centers in Guangzhou. With EVAR-first strategy, 85.7% patients with rAAA in 2020 underwent endovascular repair, similar to that in 2018 and 2019. The surgical outcomes during the pandemic were not inferior to that in 2018 and 2019. The average length of ICU stay was 1.8 ± 3.4 days in 2020, tending to be shorter than that in 2018 and 2019, whereas the length of hospital stay was similar among 3 years. The in-hospital mortality of 2018, 2019, and 2020 was 37.5%, 25.0%, and 14.3%, respectively. Three patients undergoing emergent surgeries were suspected of COVID-19, though turned out to be negative after surgery.

Conclusions: Our experience for emergency management of rAAA and infection prevention for healthcare providers is effective in optimizing emergent surgical outcomes during the COVID-19 pandemic.

INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) has become a global health crisis affecting numerous lives worldwide. An unprecedented lockdown to slow the spread of the virus was implemented in Wuhan city from January 23 to April 8, 2020, with social distancing and quarantine policy also applied across China, the growth curve peaked and flattened, with a total of 92,322 confirmed cases and 4,749 deaths reported by China CDC till May 7, 2020. Meanwhile, this pandemic is accelerating globally and has caused 51,595,737 infections and 1,274,526 deaths worldwide by May 7, 2020,¹ severely compromising healthcare provision. Unfortunately, healthcare professional's infections have also become overwhelming, with over 3,000 healthcare provider infections across China till March 6, 2020.² Among 315,531 United States COVID-19 cases reported to CDC during February 12-April 9 in 2020, a total of 9,282 were identified as health care personnel.³

Under this severe pandemic, the availability and accessibility of medical service for other emergencies have become more challenging, increasing concerns about the treatment strategy for cardiovascular diseases like acute myocardial infarction.⁴⁻⁶ However, comparable studies for vascular emergencies remain scarce. Importantly, several vascular emergencies, such as ruptured abdominal aortic aneurysm (rAAA), complicated Stanford type B aortic dissection (TBAD), visceral arterial embolism, and lower extremity arterial embolism, are life and organ-threatening for numerous patients, which should not be neglected during this global crisis. Indeed, rAAA represents a deadly vascular emergency which accounts for deaths of at least 44.6 per 100,000 population annually,⁷ with a 31% of 30-day mortality

after intervention.⁸ During this pandemic, any potential delay in surgery for rAAA could be a catastrophe, but at the same time patients with concomitant COVID-19 may pose an enormous risk to healthcare professionals. Thus, salvaging patients with rAAA while avoiding healthcare professional's infection represents a critically important and difficult problem.

The current study aimed to retrospectively assess our management of emergency surgery for rAAA under the COVID-19 pandemic.

PATIENTS AND METHODS

Study Design

Guangdong Vascular Surgery Quality Initiative (GVQI) is a consortium of 21 vascular centers, with a coordinating center at Sun Yat-sen University, collecting and analyzing vascular surgery data to improve patient outcomes in Guangdong, a province located in Southern China with a population of over 100 million. A total of 1,413 COVID-19 patients by March 23 in Guangdong made it the province with a second largest number of infections in China. Moreover, Guangdong is the province with the largest size "floating population" in China, further hindering infectious disease control due to the high mobility. To confront these challenges, a therapeutic strategy, which included a perioperative workflow and protection against cross-infection for optimization of emergent vascular surgeries and minimization of healthcare professionals infection, was established and followed in all 21 centers under the work frame of GVQI.⁹ In order to evaluate the therapeutic quality for rAAA during the COVID-19 pandemic, all rAAA patients receiving surgery between January 23 and March 23 were retrospectively reviewed in 11

vascular centers that treated rAAA in 2018, 2019, and 2020. Data of epidemiology, clinical features, laboratory and imaging examinations, treatments, outcomes, and follow-up were retrieved with a standardized data collection form. The study was approved by the Institutional Review Board of the First Affiliated Hospital of Sun Yat-sen University, the coordinating center of GVQI, with written informed consent waived for its retrospective data collection.

To investigate surgeries for vascular emergencies complicated with COVID-19 during the pandemic across China, an online survey including 62 vascular centers in 31 provinces or autonomous regions were conducted. Information regarding rAAA with concomitant COVID-19, other vascular emergencies receiving surgery, and vascular professional's infection were collected.

Personal Protection Equipment in Practice

Personal protection equipment (PPE) was stratified according to applied settings and potential exposure hazards. Level 1 protection was applied in general medical contact with non-infected patients, which required surgical mask (or N95 respirator), disposable cap, disposable isolation gown (or white coat), medical gloves (if necessary), rapid hand disinfection solution. Level 2 protection was applied in surgery for suspected patients, equipment includes disposable cap, goggles (or face shield), N95 respirator, disposable protective coverall, medical gloves, disposable shoe covers, rapid hand disinfection solution. Level 3 protection was applied in surgery for confirmed COVID-19 patients, which requires particulate respirator (or comprehensive respiratory apparatus) instead of goggles (or face shield), and an additional disposable waterproof isolation gown.¹⁰

Therapeutic Strategy

All patients with rAAA were managed according to the GVQI therapeutic strategy for emergent vascular surgeries⁹ and the Chinese Clinical guideline for COVID-19 diagnosis and treatment (6th edition) if applicable.

At arrival to the emergency room, a rigorous workflow would be followed to ensure efficient management (Fig. 1). In brief, patients were evaluated and diagnosed as abdominal aortic aneurysm with or without rupture by emergency physicians and vascular surgeons.

For an rAAA patient, and a contingency plan responding to emergent surgery under the Level 2 protection for rAAA complicated with suspected

COVID-19 would be activated immediately, while a nasopharyngeal swab for nucleic acid test and chest CT scan would be postponed to the postoperative stage if not suitable.

In 2018 and 2019, open surgery or EVAR was individually selected based on anatomy and expertise in different center. In 2020, for patients with appropriate anatomy, an EVAR-first strategy was applied, since it decreased the need for blood transfusion, given reduced blood supply during the pandemic, and shortened surgeons' exposure time to potential infection.

For patients with suspected or confirmed COVID-19, a perioperative strategy adhering to a checklist (Table 1) to prevent cross-infection in-hospital was implemented.

Follow-Up Protocols

One-month follow-up data of patients in 2018 and 2019 were used for this study. Patients in 2020 were followed up 14 days after discharge, and a phone call rather than an on-site visit was mainly applied.

Statistical Analysis

Continuous parameters are expressed as mean \pm SD or median (IQR), and the differences between years compared with One-way ANOVA if data were normally distributed and Kruskal-Wallis test if the data were not normally distributed. Categorical parameters are expressed as frequencies and percentages and were compared with Fisher's exact-test. *P* value < 0.05 (based on 2-sided tests) is considered as significantly different. The analyses were performed using Stata version 14.0 (StataCorp).

RESULTS

Baseline Characteristics

A total of 14 rAAA patients admitted to 11 centers from January 23 to March 23, 2020, were treated following the treatment flowchart in appliance with the instruction of GVQI (Fig. 1). In comparison, 8 and 12 patients with rAAA were treated during the corresponding period in 2018 and 2019, respectively, indicating that the upward trend of rAAA patients was not reversed in 2020 under the COVID-19 pandemic. Patients' age and gender ratio were similar in those 3 years. Eleven patients tested negative preoperatively, while 3 underwent emergent surgery before results of the COVID-19 screen were available, but tested negative postoperatively. The parameters including comorbid

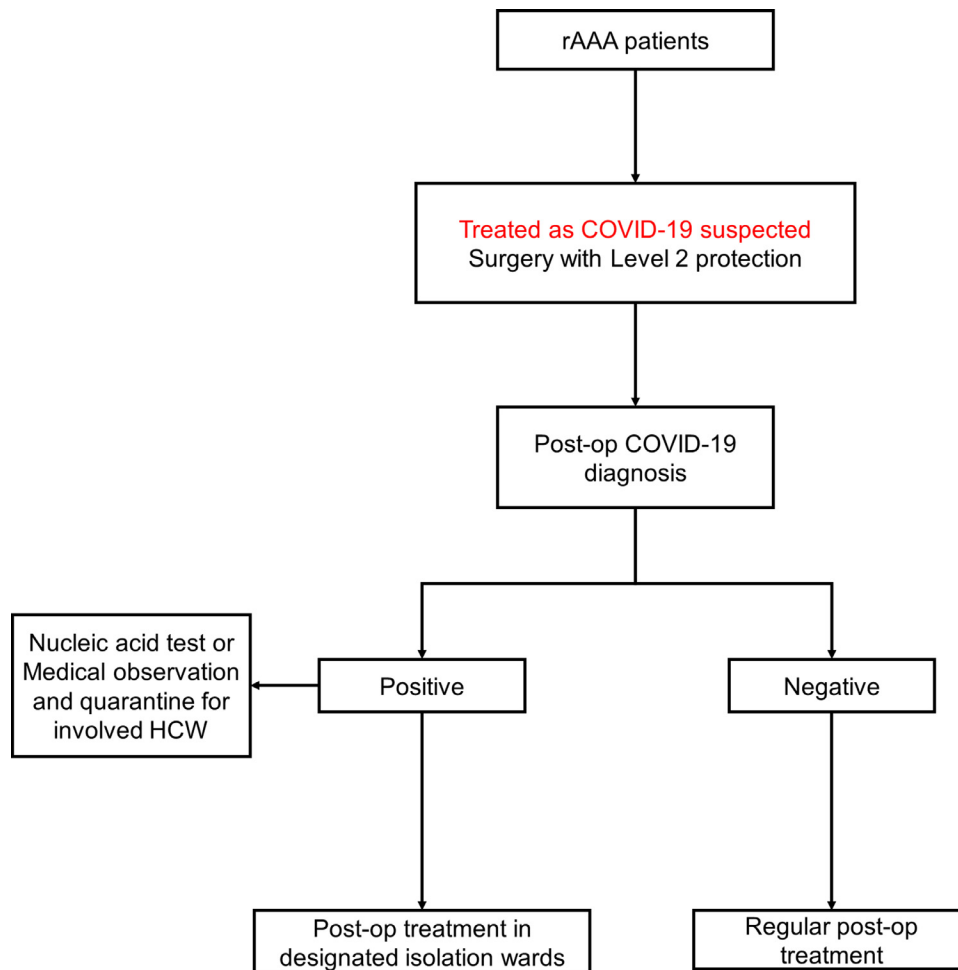


Fig. 1. Management flowchart for patients with ruptured abdominal aortic aneurysm.

hypertension, hyperlipidemia, and diabetes, history of cardiovascular surgery, etiology, hemodynamic instability, creatinine, hemoglobin, maximum aneurysm diameter, and aortic neck length were similar among the 3 groups (Table II). Taken together, a slightly higher number of rAAA patients with comparable baseline characteristics were treated in 2020, suggesting that the availability and accessibility of medical service for rAAA was likely not impaired during the COVID-19 pandemic.

Perioperative and Follow-Up Data

With the EVAR-first strategy, the choice of endovascular repair was dominant in 2020, similar to 2018 and 2019 (87.5%, 91.7%, and 85.7% for 2018, 2019, and 2020, respectively). General anesthesia was least applied in 2019 (87.5%, 41.7%, and 85.7% in 2018, 2019, and 2020, respectively, $P < 0.05$). The duration of surgery, blood loss, and blood transfusion were similar among the 3 groups, while technical success was achieved

for all patients. Perioperative complications, including cardio-cerebrovascular complications, respiratory complications, acute renal failure, bowel ischemia, and graft-related complications were not significantly different among groups. The average length of ICU stay was 1.8 ± 3.4 days in 2020, tending to be shorter than 3.3 ± 4.1 days in 2018 and 4.9 ± 9.6 days in 2019, whereas the length of hospital stay was similar among groups. The in-hospital mortality of 2018, 2019, and 2020 was 37.5%, 25.0%, and 14.3%, respectively, and thus seemed to be improved yearly (Table III). Collectively, these results suggested that the therapeutic efficacy for rAAA in 2020 was not compromised under the COVID-19 pandemic, but tended to be improved.

Patient Referral during the COVID-19 Pandemic

Notably, the percentage of rAAA patients treated in large medical centers in Guangzhou, the provincial

Table I. Checklist for vascular emergency surgeries with concomitant suspected or confirmed COVID-19.

	Key measures	Check
Preoperation		
Patient transfer	Designated routes and elevators Level 2 protection for medical staff involved Transfer bed staying in the surgery room after entry	
Operating theatre	Operating theatre/hybrid room with negative pressure or isolated air purification units Irrelevant items & equipment evacuated	
PPE	Suspected COVID-19: Level 2 protection Confirmed COVID-19: Level 3 protection	
Intra-operation		
Patient	Local anesthesia: mask on during the entire surgery General anesthesia: disposable filter between endotracheal tube & respiratory circuit	
Staff	Minimize participants and access Avoid splash of blood and body fluid	
Postoperation		
Patient recovery	Stay in the surgery room during recovery	
Patient transfer	Level 2 protection for medical staff involved Designated routes and elevators Isolation intensive care unit/ward	
Staff	If occupational exposure suspected Nucleic acid test Close medical observation	

Table II. Baseline characteristics of patients with ruptured abdominal aortic aneurysm.

	2018	2019	2020	P
No. of patients	8	12	14	
Age (year) ^a	67(63,69)	71(68,84)	63.5(58,69)	0.098
Male gender (%)	7(87.5)	10(83.3)	12(85.7)	1.00
Suspected COVID-19	NA	NA	3	
Confirmed COVID-19	NA	NA	0	
Hypertension	5(62.5)	9(75.0)	8(57.1)	0.661
Hyperlipidemia	1(12.5)	2(16.7)	4(28.6)	0.768
Diabetes	2(25.0)	3(25.0)	1(7.14)	0.451
History of cardiovascular surgery	1(12.5)	4(33.3)	3(21.4)	0.678
Etiology: atherosclerosis	5(62.5)	5(41.7)	10(71.4)	0.372
mycotic	0	1(8.3)	2(14.3)	0.775
Hemodynamic instability	2(25.0)	3(25.0)	3(21.4)	1.00
Creatinine (mg/L) ^a	120(81,234.6)	84.2(74.5,169.5)	80(70,149.6)	0.530
Hemoglobin (g/L) ^b	92.6±32.8	88.2±23.2	110.0±24.2	0.0977
Maximum aneurysm diameter (mm) ^b	64.6±24.5	63.4±19.3	72.4±18.9	0.490
Aortic neck length (mm) ^a	26(10.1,35)	25(24,40)	24(20,45)	0.591

^aMedian (IQR), Kruskal-Wallis test was used for comparison.

^bMean±SD, one-way ANOVA was used for comparison.

capital of Guangdong province, was significantly decreased in 2020 (75%, 75%, and 42.9% in 2018, 2019, and 2020, respectively). Similarly, a significant reduction of rAAA patients was noticed in 6 centers in Wuhan (2, 6, and 0 rAAA patients from January 23 to March 23, 2018, 2019, and 2020, respectively), possibly because several large vascular centers were transformed into isolation

wards for COVID-19 patients. Interestingly, local hospitals treated an increased percentage of rAAA patients and achieved a similar outcome in 2020 when compared with large centers in Guangzhou (Fig. 2). These suggested that patient referral to large centers might have been impacted by the quarantine policy, yet the treatment efficacy was not compromised in local centers.

Table III. Perioperative and follow-up data for patients with ruptured abdominal aortic aneurysm.

	2018	2019	2020	P
No. of patients	8	12	14	
EVAR	7(87.5)	11(91.7)	12(85.7)	1.00
General anesthesia	7(87.5)	5(41.7)	12(85.7)	0.026
Duration of surgery (min) ^a	132.5(84,180)	120(90,132)	137.5(60,180)	0.740
Blood loss (mL) ^a	125(20,400)	150(60,200)	50(20,100)	0.637
Blood transfusion (U) ^b	2.6±3.5	2.3±3.3	2±2.5	0.910
Technical success	100%	100%	100%	NA
Cardio-cerebrovascular complication	1(12.5)	1(8.3)	1(7.1)	1.000
Respiratory complication	2(25.0)	3(25.0)	2(14.3)	0.756
Acute renal failure	1(12.5)	3(25.0)	0	0.103
Bowel ischemia	2(25.0)	2(16.7)	1(7.1)	0.592
Graft-related complication	0	3(25.0)	1(7.1)	0.327
In-hospital reintervention	0	1(8.3)	1(7.1)	1.000
Length of stay in ICU (days) ^b	3.3±4.1	4.9±9.6	1.8±3.4	0.517
Length of hospital stay (days) ^b	14±10.8	13.2±9.2	9.2±5.7	0.479
In-hospital death	3(37.5)	3(25.0)	2(14.3)	0.455
Follow-up				
Graft-related complications	0	0	N/A	
Overall death	0	0	0	

EVAR, endovascular aortic repair, ICU, intensive care unit.

^aMedian (IQR), Kruskal-Wallis test was used for comparison.

^bMean±SD, 1-way ANOVA was used for comparison.

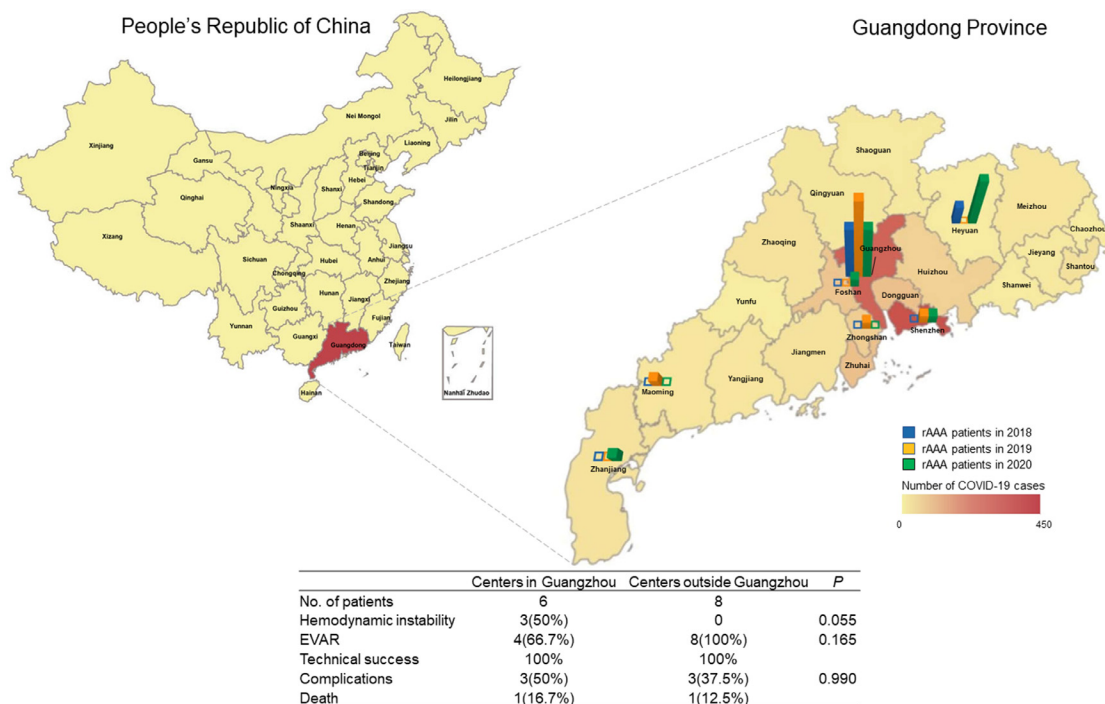


Fig. 2. Spatial distribution of patients with ruptured abdominal aortic aneurysm during COVID-19 pandemic in Guangdong.

A Constellation of Vascular Emergency Surgeries With Concomitant COVID-19 in China

A total of 11 vascular emergencies with concomitant COVID-19 received emergent surgeries in 62 surveyed centers with a similar treatment strategy.¹¹ These patient series included 4 complicated TBAD, five extracorporeal membrane oxygenation (ECMO) associated complications, one critical limb ischemia, and one pulmonary embolism secondary to deep venous thrombosis. Although the Level 3 protection may reduce surgeons' flexibility and increase surgical difficulty, technical success was achieved in all these procedures. Moreover, infection of vascular professionals was not reported in all these 62 centers responding the survey. These data demonstrated that our treatment and prevention strategy could be applicable and beneficial to other types of vascular emergencies with concomitant COVID-19.

DISCUSSION

The current study shows that the number of rAAA treated in Guangdong, China increased each year, and this upward trend was not reversed in 2020. More importantly, the therapeutic outcomes of rAAA were not compromised under the COVID-19 pandemic. Comparing with small centers in local cities, a smaller percentage of cases was treated in large medical centers in Guangzhou, the provincial capital of Guangdong, than in local hospitals.

Preservation of essential medical services for other medical emergencies represents a critically important issue and a difficult challenge under this pandemic. A total of 2,489 healthcare providers from Guangdong participated in supporting the frontline in Hubei province, and plenty of medical resources including PPE had also been donated. Being aware of reduced medical staff and potentially compromised surgical facility for emergency surgery, we sought the best strategy to continue the proper management for these patients and protect key resources for combating COVID-19. Our results showed that quality treatment for rAAA was well preserved when a proper therapeutic strategy was applied. However, this could be compromised once the healthcare system became overloaded. Notably, increased percentage of cases were treated in smaller cities with favorable outcomes, confirming that quarantine might decrease patient referral from distant cities to large medical centers. Receiving emergent operation on-site in qualified local hospitals is therefore recommended during the COVID-19 outbreak, as it may yield comparable

therapeutic outcomes as well as reduce potential spreading of infection.

The rAAA is a deadly vascular emergency that may consume considerable medical resources, so that a package of measures should be adopted to ensure timely operations with a minimal burden on the healthcare system under this pandemic. A meta-analysis of recent studies on rAAA showed that EVAR resulted in a perioperative mortality of 24.5%, lower than 37.8% for open surgery, and a less blood loss.⁸ Considering that blood supply was decreased by about 30% during the pandemic, an "EVAR-first" strategy was recommended for every patient with appropriate anatomy. In fact, EVAR accounted for 85.7% of all procedures and achieved favorable outcomes. Of note, the average length of ICU stay tended to be shorter in 2020, likely secondary to the strategy to protect key resources for combating COVID-19.

While any potential delay in surgery for rAAA could be catastrophic, a single rAAA patient with unidentified COVID-19 may pose an enormous risk to a large number of healthcare professionals. Therefore, a proper and practical therapeutic strategy for salvaging patients with rAAA while in parallel reducing healthcare professional infections is of critical importance. One may argue that because there was actually no rAAA complicated with COVID-19 in Guangdong, extensive screening of coronavirus was probably not justified. It is worth pointing out that, poor awareness of personal protection and insufficient PPE at the early stage of the COVID-19 outbreak may partially explain the high incidence of medical workers infection in general wards,¹⁰ in contrast to the zero infection rate for 42,600 healthcare workers who participated in supporting Hubei's battle against the pandemic with proper protection.¹² Unfortunately, health workers infection has been overwhelming in many countries worldwide. Therefore, proper protection for healthcare professionals is of critical importance during this long battle against COVID-19. Nevertheless, this protection strategy demands adequate healthcare resources including abundant PPE and coronavirus testing kits, and must be tailored to individual centers to achieve an optimal outcome.

STUDY LIMITATIONS

Our study has several notable limitations. First, it was a retrospective study with small sample size, as rAAA represents a rare situation. Second, because a large number of patients with rAAA are also treated by cardiac surgeons and interventional

physicians across China, our data solely collected from vascular centers may suffer from selection bias. Nevertheless, we believe that our strategy would be applicable to other specialties and that this management experience can add value to the battle against Coronavirus.

CONCLUSION

In summary, our experience to provide suitable treatment for rAAA patients were proved with acceptable surgery success rate and short term prognosis, and can also be applicable and beneficial to patients with other life-threatening vascular emergencies and healthcare professionals involved.

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